Cone Penetrometer

An Enabling Technology for Characterization and Monitoring Systems

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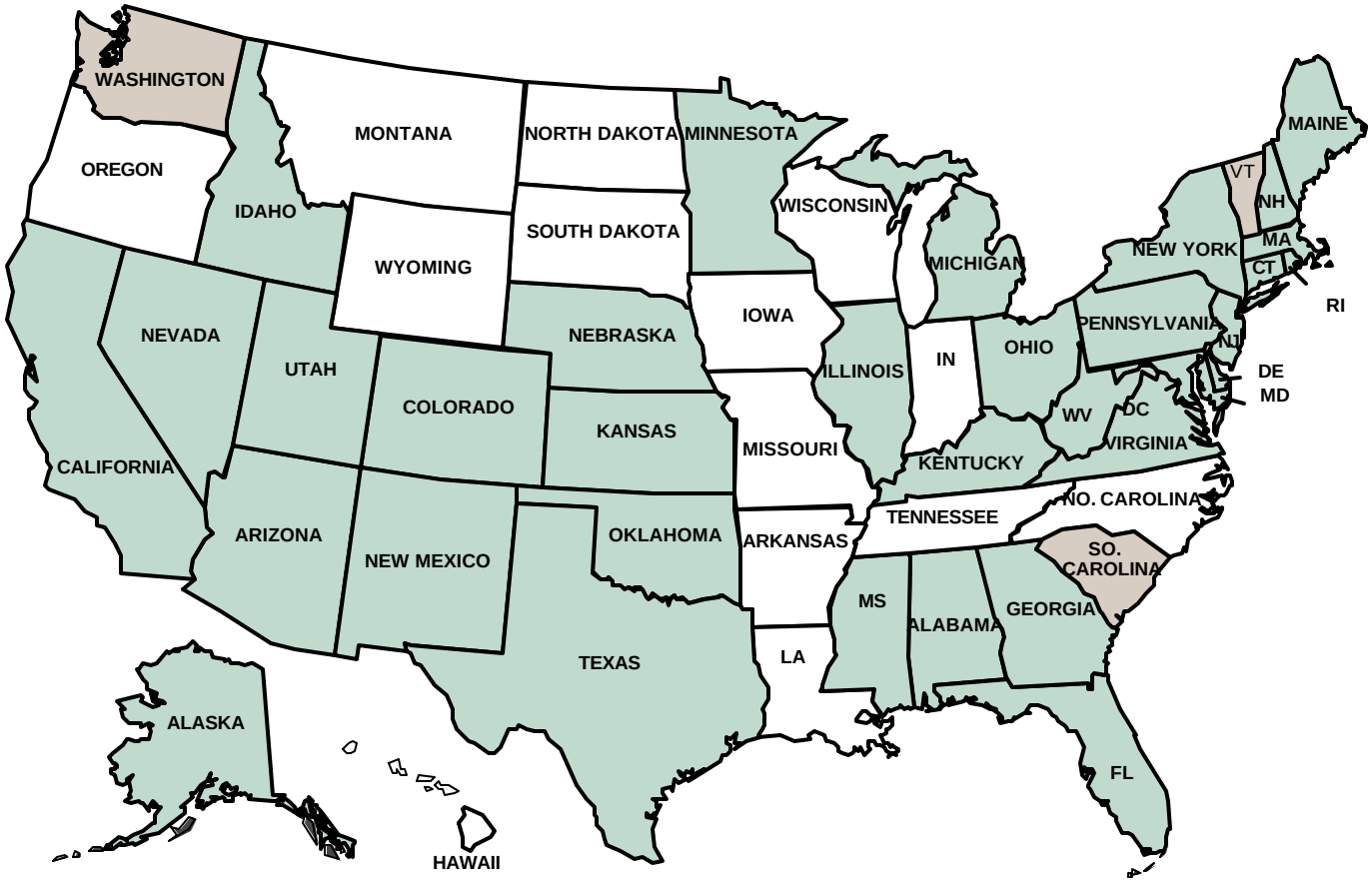
Outline

- **History**
  - CPT use at DOE facilities
  - DOE developed Tools
- **Characterization Technologies**
  - Platforms
  - Sensors
  - Samplers
- **Monitoring Approaches**
  - Soil gas monitoring points
  - Monitoring wells
  - CPT installed Sensor Networks
- **Summary**

History

- Developed in Netherlands in 1934
- 1990 DOE begins working with industry to advance technology for environmental applications.
- >400,000 ft conducted at SRS since 1989
- >6,000 ft conducted at Hanford since 1991
- >1,000 ft conducted at NTS
- Also used at SNL, INEEL, Paducha, Pantex
- Basic technology is mature with new tools constantly being added.


WASHINGTON
OREGON
CALIFORNIA
IDAHO
NEVADA
MONTANA
WYOMING
UTAH
ARIZONA
COLORADO
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LA
WISCONSIN
ILLINOIS
MICHIGAN
IN
OHIO
KENTUCKY
TENNESSEE
MS
ALABAMA
GEORGIA
FL
SO. CAROLINA
NO. CAROLINA
VIRGINIA
WV
DC
PENNSYLVANIA
NEW YORK
VT
NH
MA
CT
RI
NJ
DE
MD
MAINE
ALASKA
HAWAII
States with Applied Research CPT Experience
Operating Locations

DOE Developed Technologies

1990 DOE begins working with industry to advance technology for environmental applications.

- Laser Induced Fluorescence Sensor
- Electrical Resistance & Soil Moisture
- Heavy Weight (30 Ton) CPT
- UTD Polo Tracking System
- Raman Spectroscopy
- High-Speed Gas Chromatography
- Wireline CPT
- Raman Spectroscopy
- High-Speed Gas Chromatography
- Laser Induced Breakdown Spectroscopy (LIBS)
- Permeability Probe
- Sonic CPT
- Gamma Spectroscopy
- X-Ray Fluorescence Sensor for Metals

30-ton CPT Rig

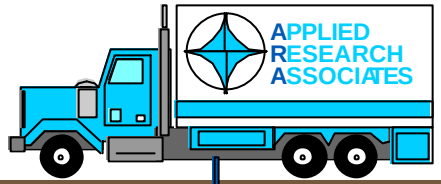
Hanford Penetration Platform

Track Mounted Units

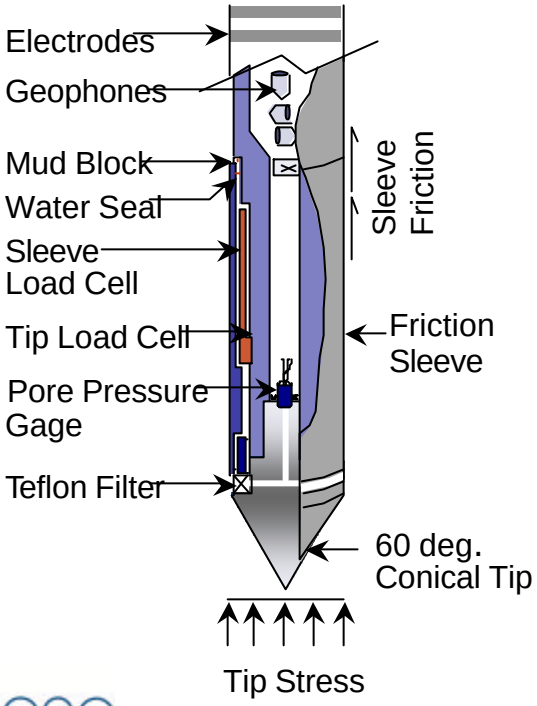
CPT Toolbox

- **Characterization Sensors**
  - Soil Stratigraphy & Type
  - Soil Moisture and Resistivity
  - Video Imagery
  - Gamma Spectroscopy (beta ?)
  - Raman Spectroscopy
  - Fluorescence Probes
  - pH, Temperature, ORP
  - DNAPL Sensors?
  - Air and Water Permeability
  - Wireline CPT
- **Sampling**
  - Soil, Water, Soil Vapor
- **Monitoring System**
  - Networked sensors
  - Electrical Resistance Tomography (ERT)
  - Monitoring Wells
- **Remediation Installations**
  - Steam Injection
  - Soil Vapor Extraction
  - Six-Phase Heating Feasible
  - Reactive Barrier Feasible

Standard Cone Penetrometer and Sampling Systems

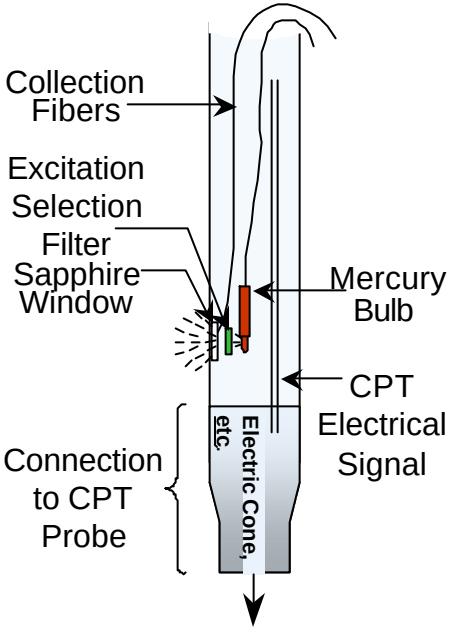


Schematic of ARA's Cone Penetrometer Probe

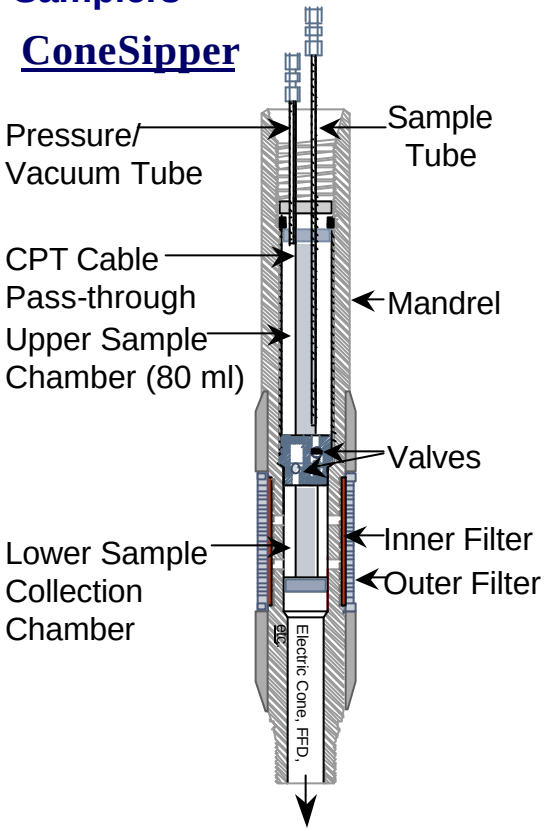


Schematic of Samplers

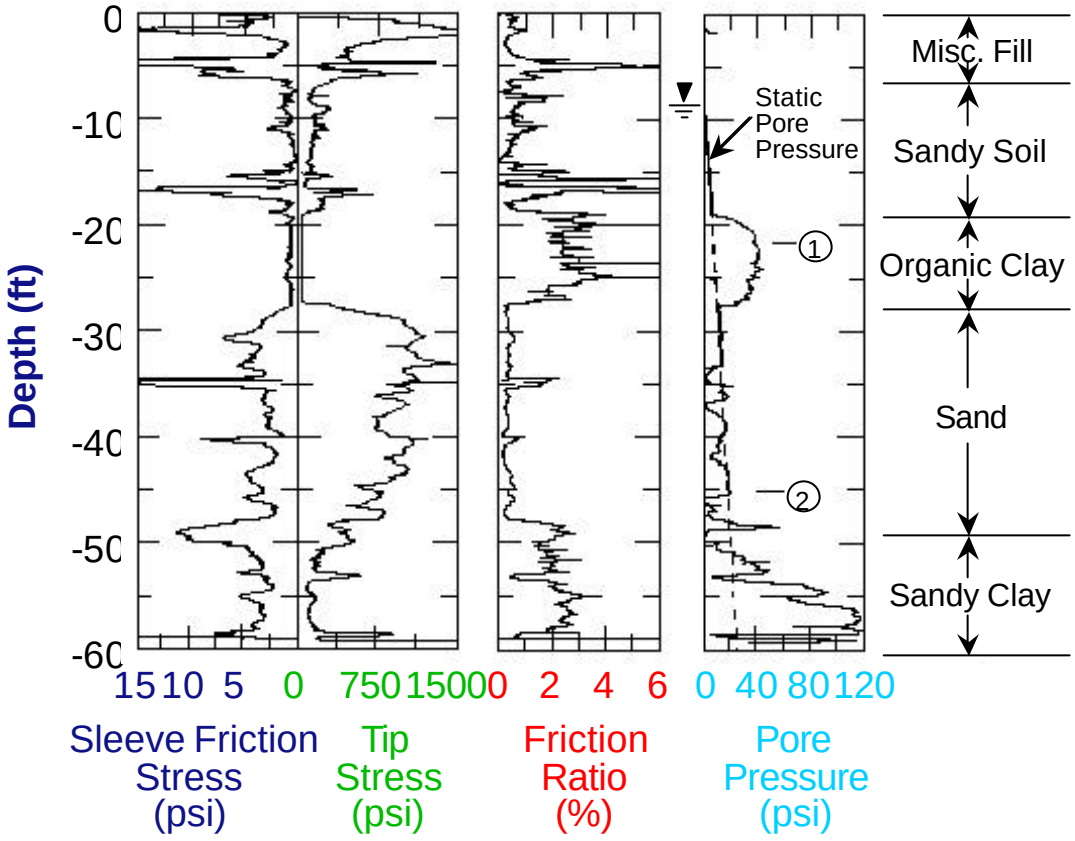
FFD

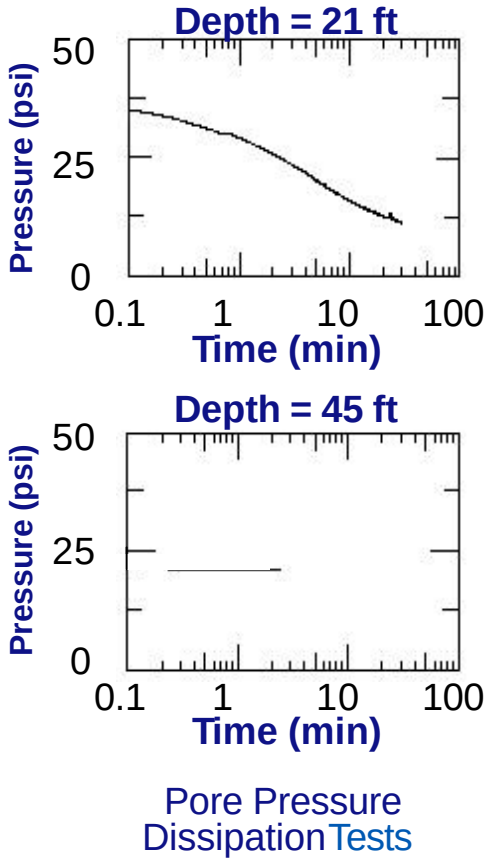


ConeSipper



Data from Standard Cone Penetrometer Test

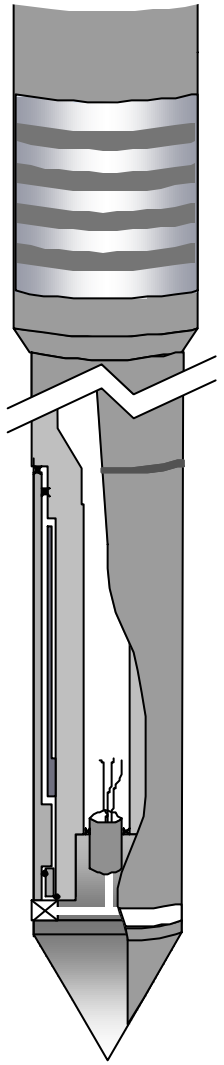




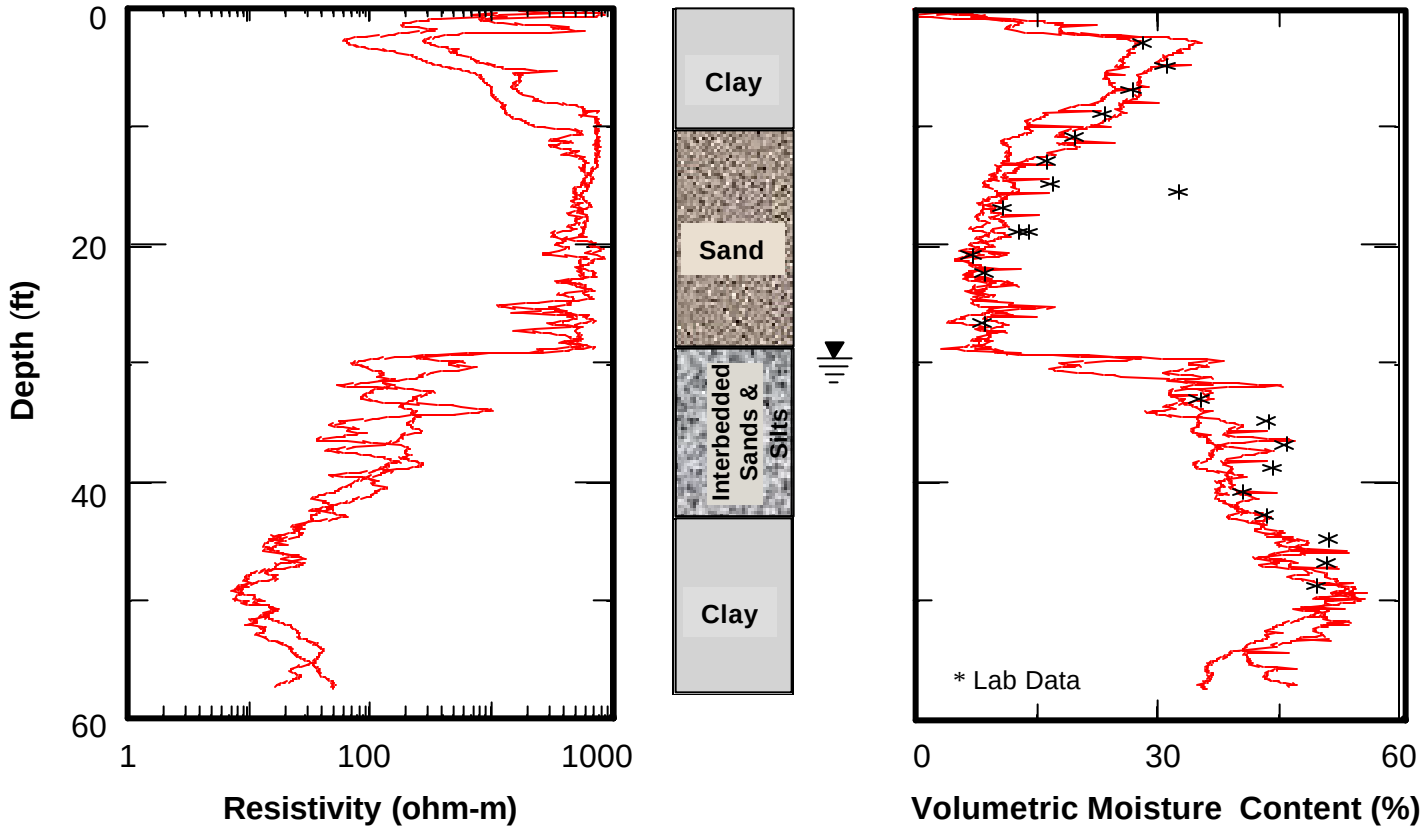
Pore Pressure Dissipation Tests

SMP Probe Features

- Simultaneous measurement of soil resistivity and apparent dielectric (e_a)
- Correlation of dielectric to q (volumetric soil moisture)
- For saturated sites, porosity = q
- Dielectric measured at 100 MHz, hence minor influence of conductivity on e_a
- SMP outputs voltage directly into A/D system

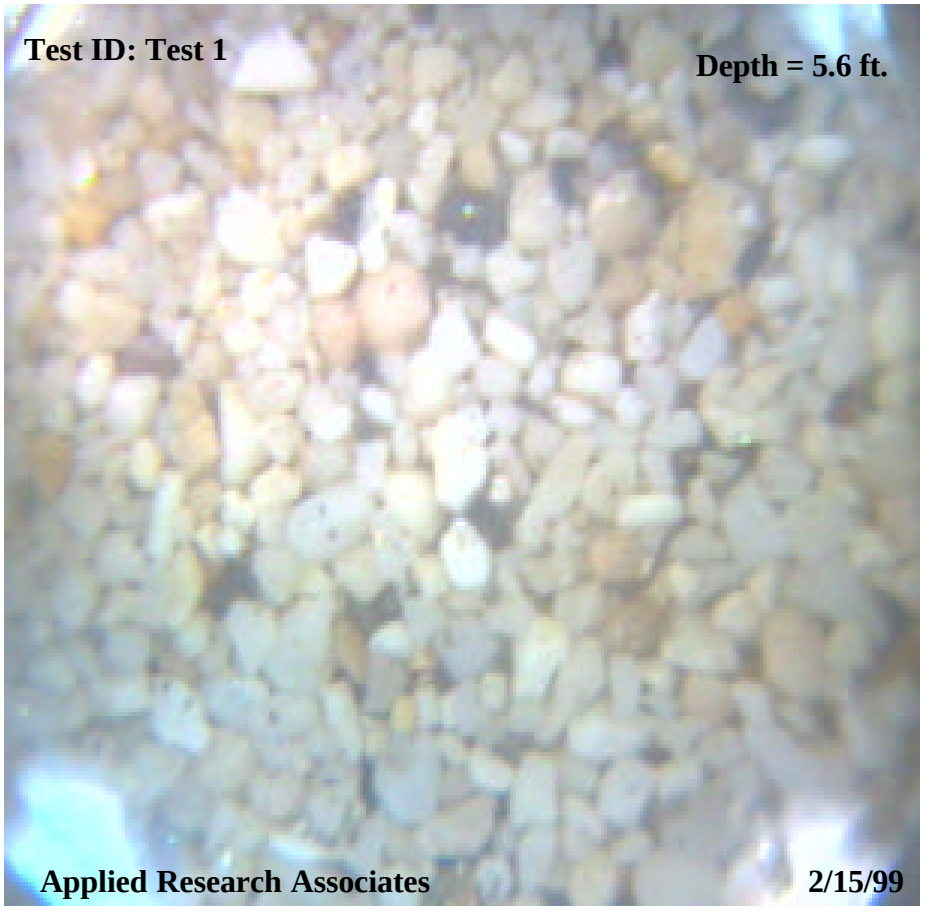


SMP Data Obtained During a Field Trial Showing Resistivity and Soil Moisture Profiles

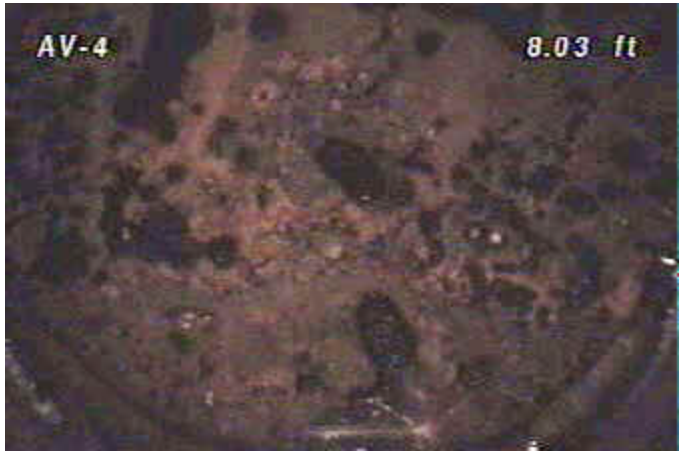


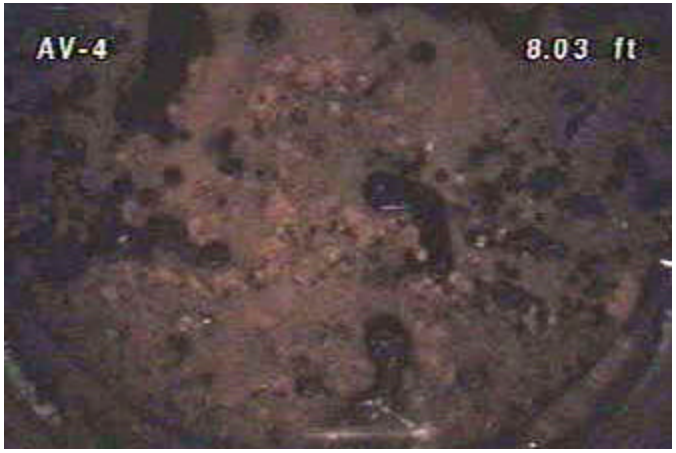
Video CPT Image

- Image has accurate color resolution
- Assists with soil classification determination
- Continuous Video Image of Penetration
- DNAPL's can be seen on video image



Video Cone images of Coal Tars at a site in NY





Gamma Radiation Sensor

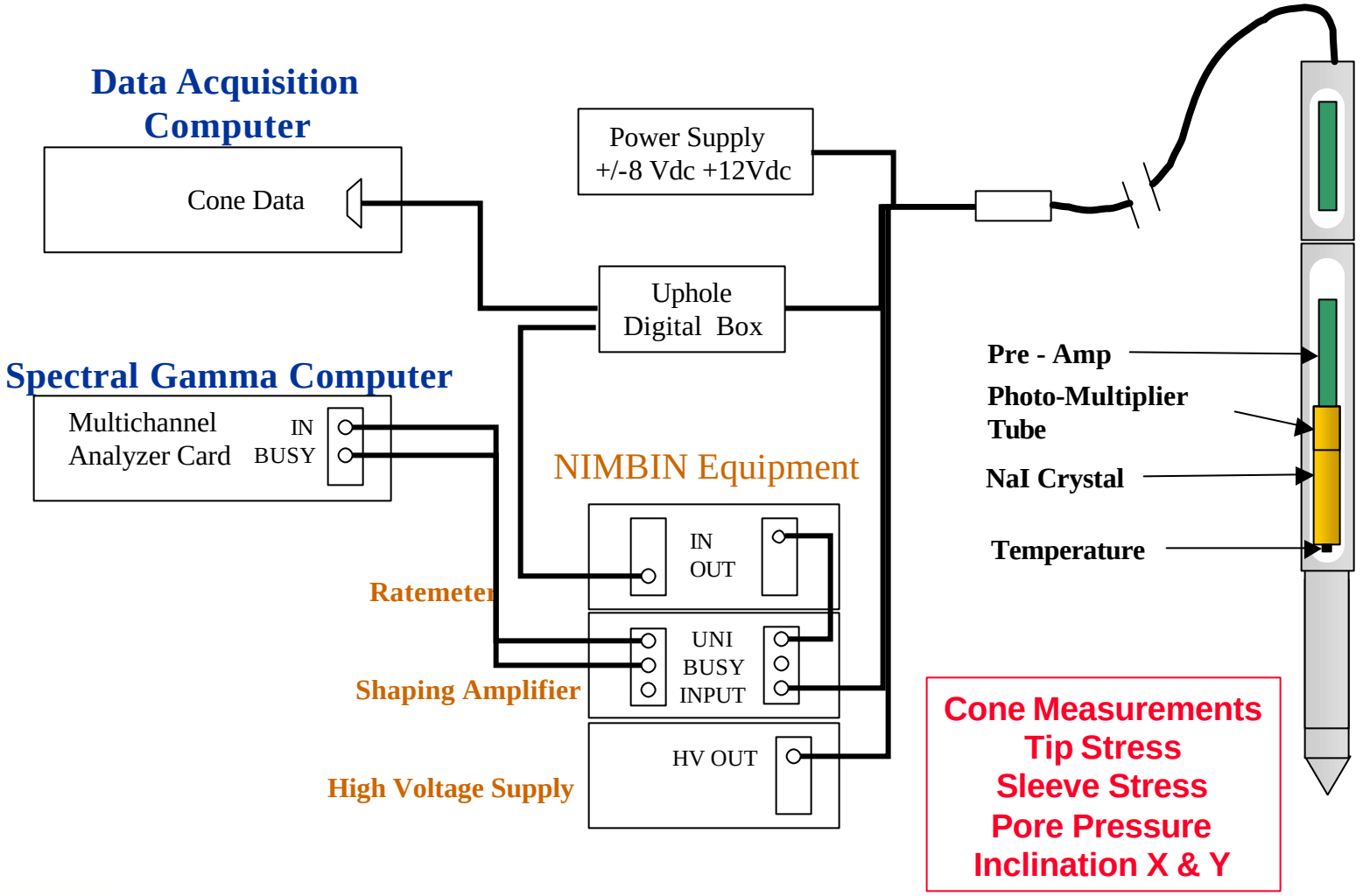
Gamma Radiation Probe and Sensor

Gamma Radiation-Cone Penetrometer Technique (Gamma-CPT) is a cost effective and intrinsically safe method for locating radiation contamination in-situ.

Advantages:

- Employees are not exposed to radioactive material, adding to site safety.
- Drilling waste is virtually eliminated, resulting in significant hazardous waste disposal cost savings.
- CPT soundings can be performed at locations considered too hazardous for conventional drilling operations.
- Time required for a Gamma-CPT sounding is significantly less than that of a conventional drilling investigation.
- Soil stratigraphy information is obtained simultaneously with radiation contamination information.

Schematic of Gamma CPT System



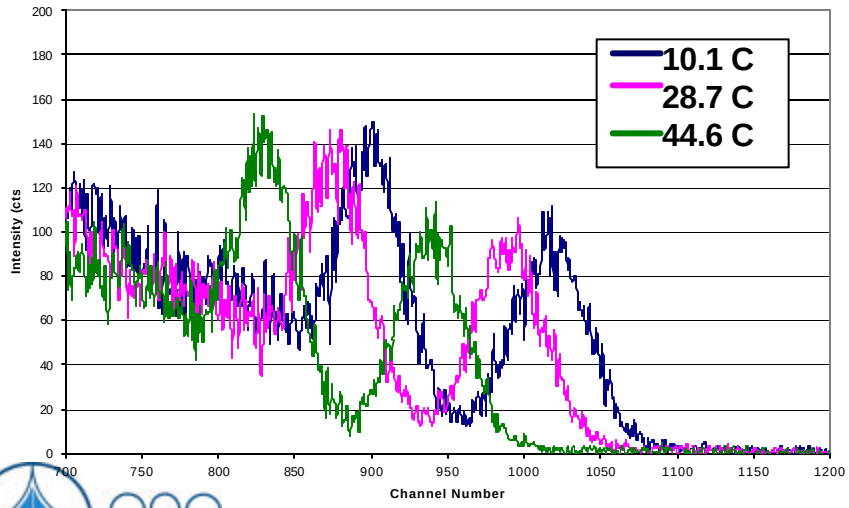
Gamma - CPT system specifications

- Continuous Total Gamma Profile during Penetration.
- Energy Range - 0 - 2.8 MeV.
  - Cesium, Cobalt, Thorium and many other gamma emitters.
- Resolution - 7.5 to 9.0 % for Cs137.
- Efficiency - 170 cnts/s/µCi for Cs137.
- Minimum Detection Limit.
  - 2 - 4 pCi/gm for Cs137
  - 4 - 10 pCi/gm for Co60

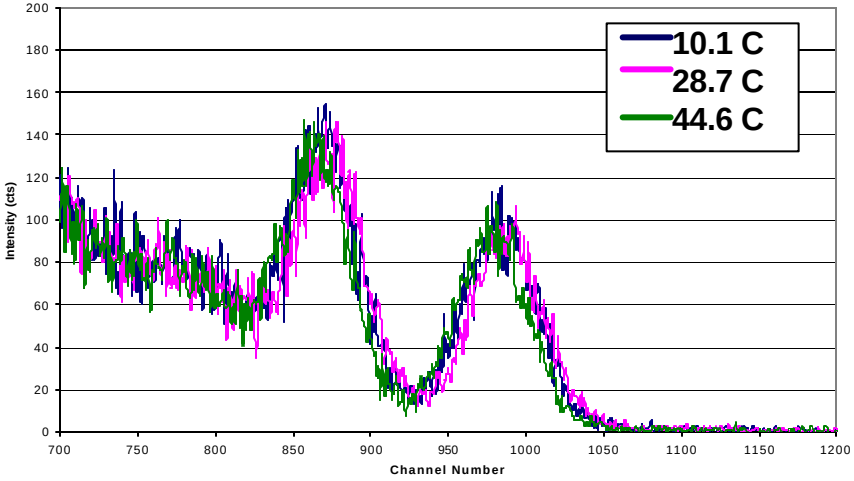
Unique System Improvements

- Improved Downhole Pre-amp
  - 1 inch configuration
  - Provides initial shaping of pulses which increases resolution
- Temperature correction routines
  - Cone under goes a large temperature change under push conditions which alters the energy calibration of the crystal.

Before Temperature Correction



After Temperature Correction



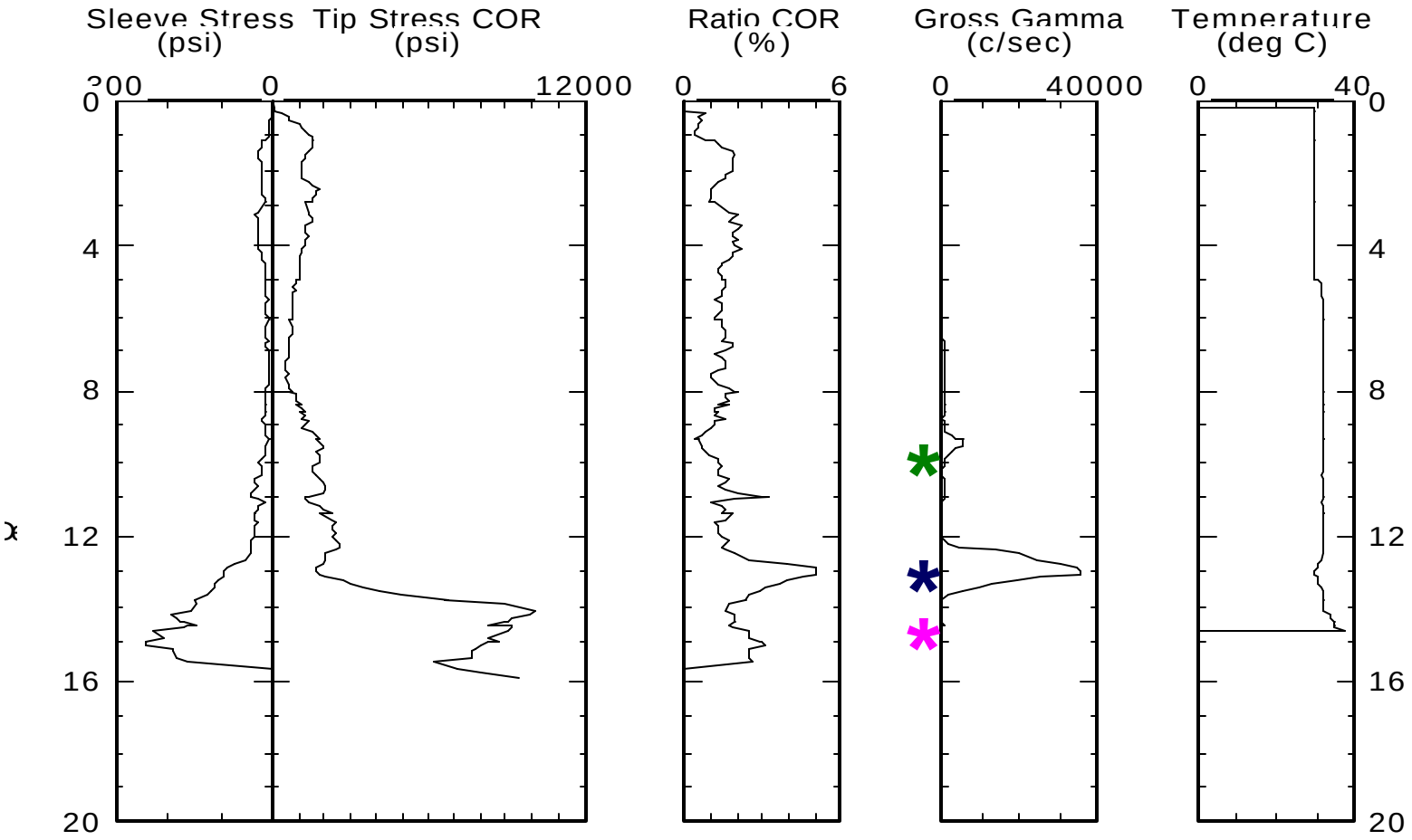
Field Investigations

- Nevada Test Site - October 1999.
  - Immediately Following TIE Conference.
  - Area 25 radiological waste dump sites.
- Hanford Complex S-Tank Farm.
  - First time CPT operations in Tank Farm.
  - Vadose Zone Characterization
- IMC Phosphate Mines
  - Detection of phosphate rich regions for Mining Characterization.
- Nevada Test Site - October 2000
  - Investigation of leach fields for radiological contamination.

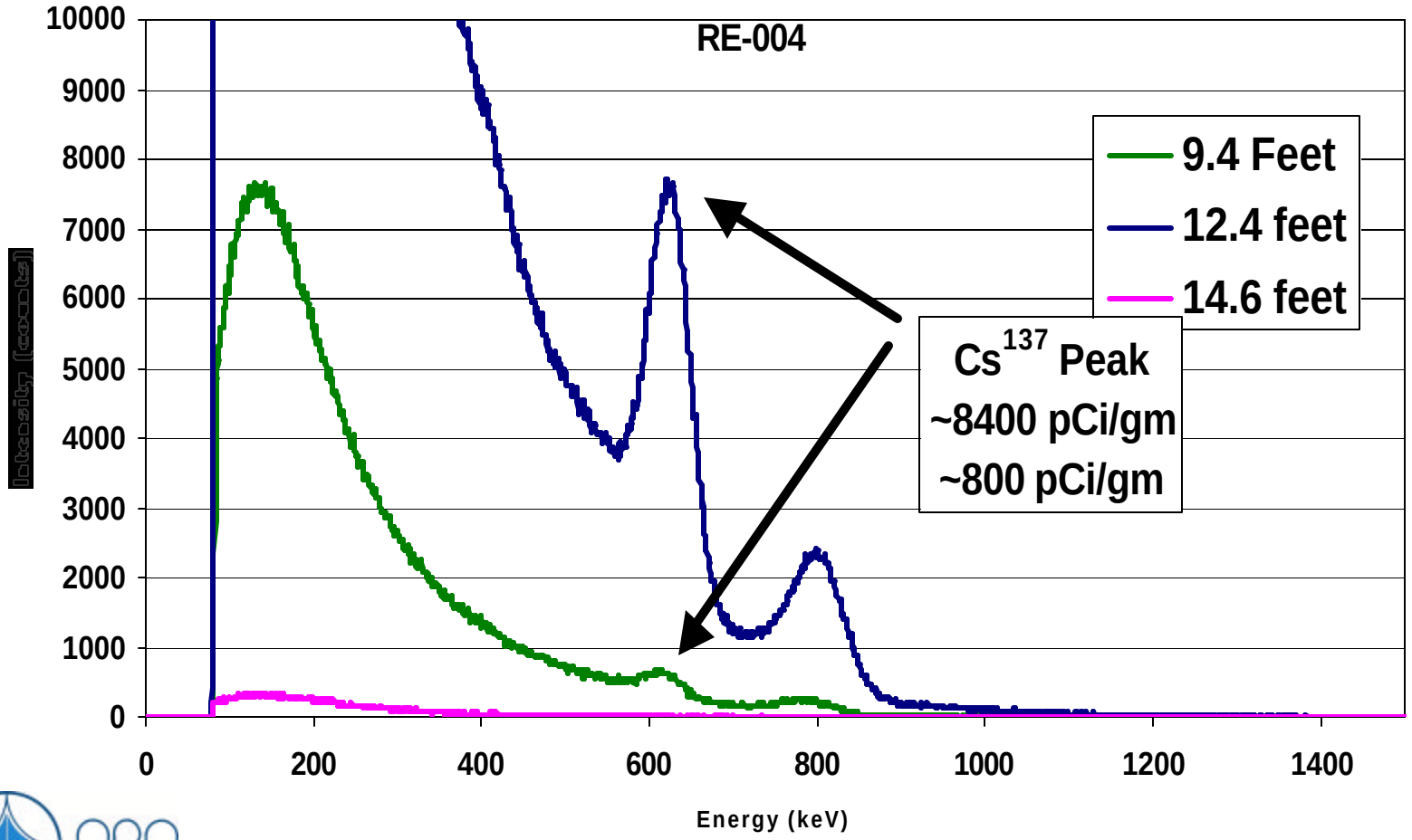
G-CPT Characterization of the RMAD and EMAD Waste Burial Sites at the Nevada Test Site.

- 80 Penetrations conducted to depths of 15 to 20 feet to characterize suspected burial waste sites.
- Identified several localized hot spots of contamination.
- Measured soil gas concentration in conjunction with the gross and spectral gamma measurements.
- Rods were wiped clean by the soils and no decontamination of the rods was necessary.

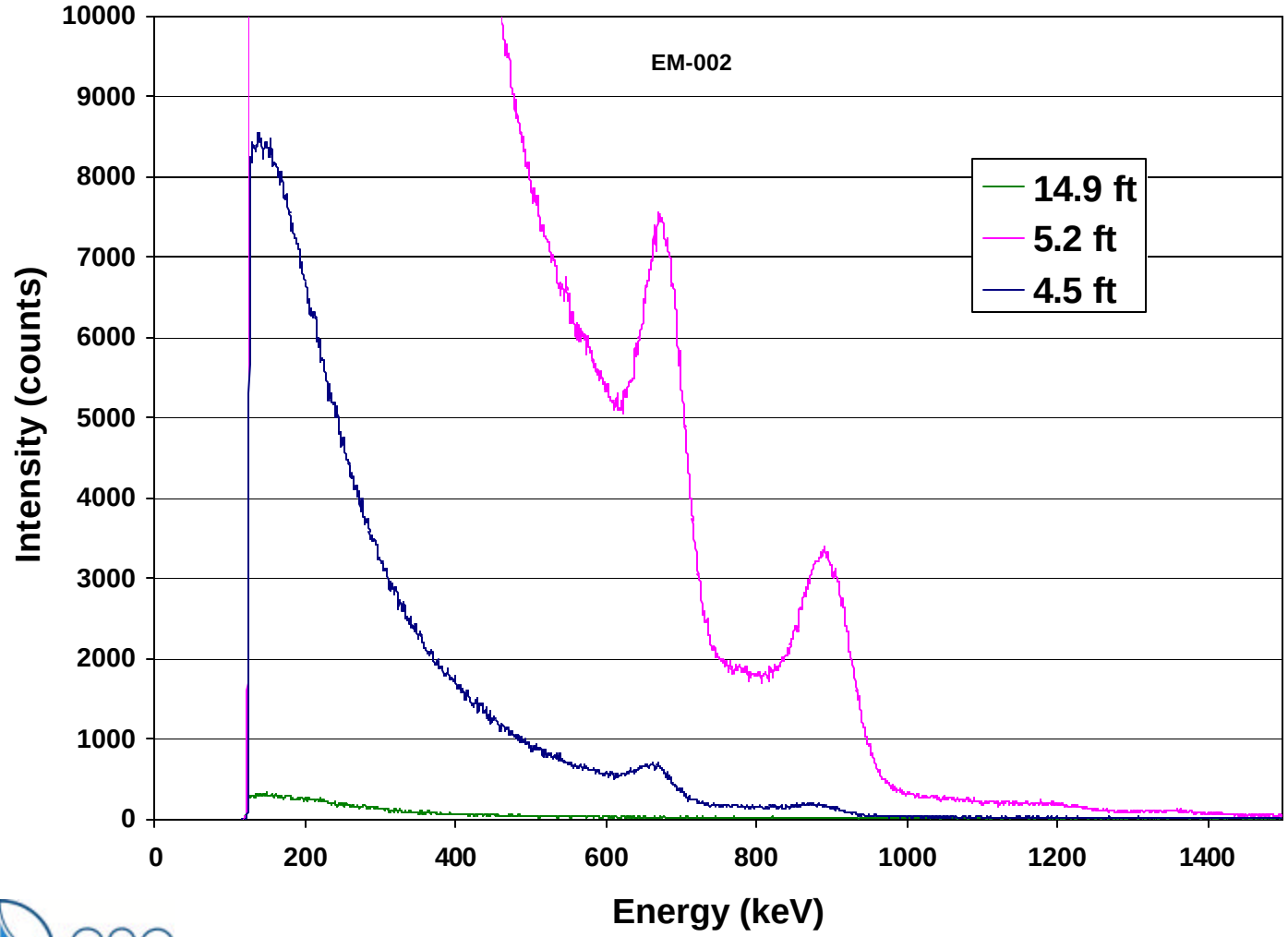
Penetration Data from NTS R-Mad Area



Spectra Data From Penetration RE-004



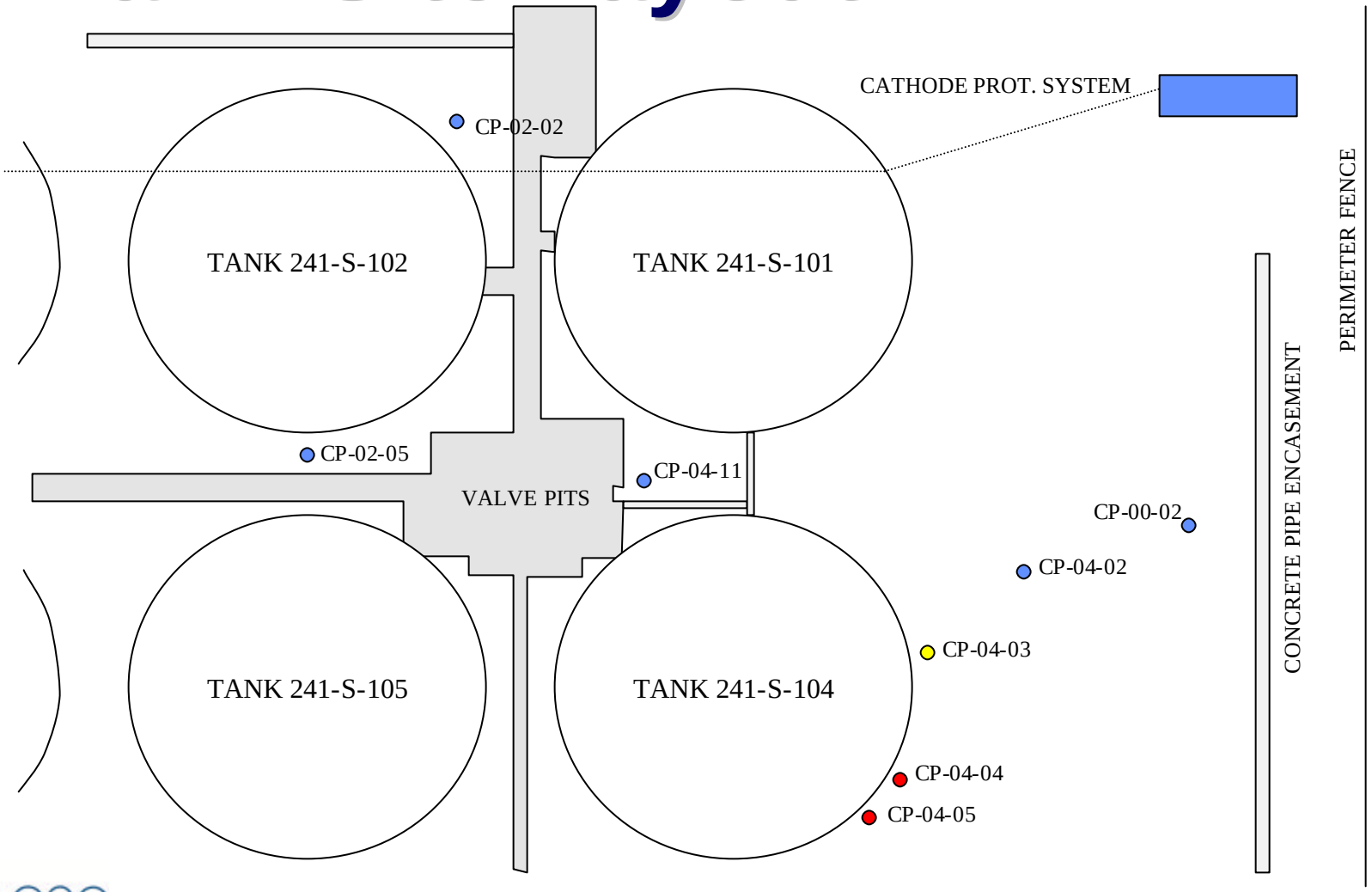
Spectra Data From Penetration EM-002



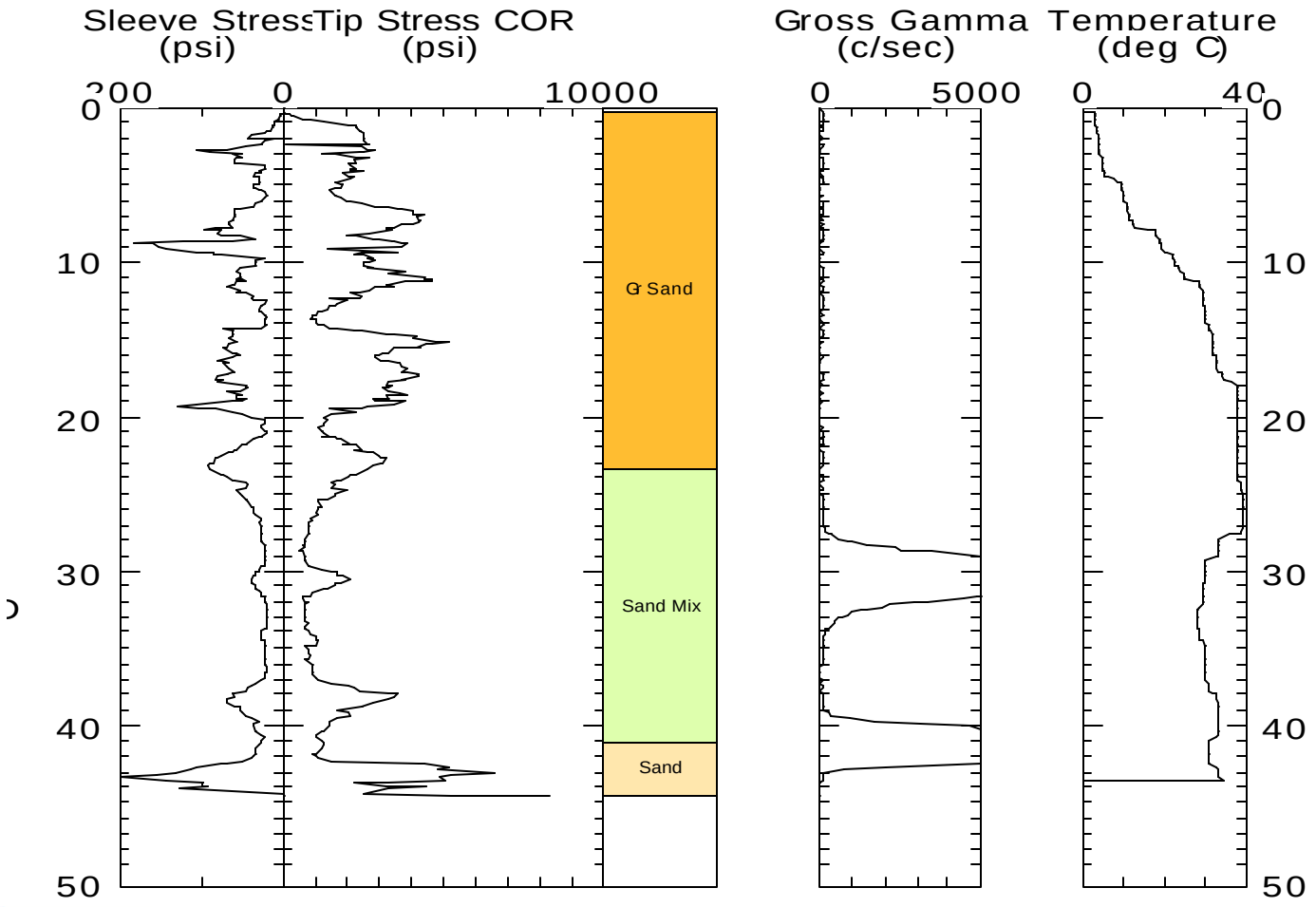
Gamma Spectroscopy CPT characterization of S-Tank Farm at the DOE Hanford Facility

- Project Accomplishments
  - 9 Gamma CPT pushes to the tank bottom of 45 feet. Recorded Gross Gamma and Spectral Gamma when count rate above 20 pCi/gm Cs^{137}.
  - Collected Soil samples in regions of 50 pCi/gm and below regions with >50 pCi/gm or Cs^{137}.
  - Detected contamination at the bottom of the tanks with count rates > 150,000 Cnts/sec.
  - All rods retrieved as clean from hole without decontamination.

S-Farm Site Layout

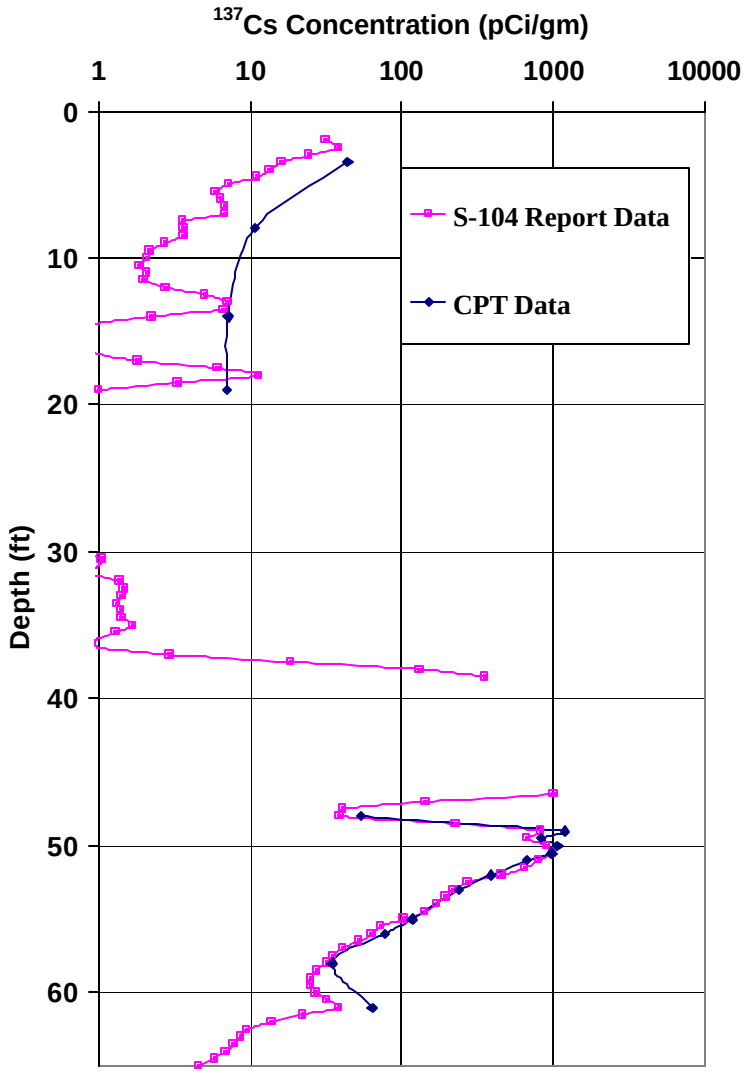


Penetration Profile from S-Farm (CP-04-04)

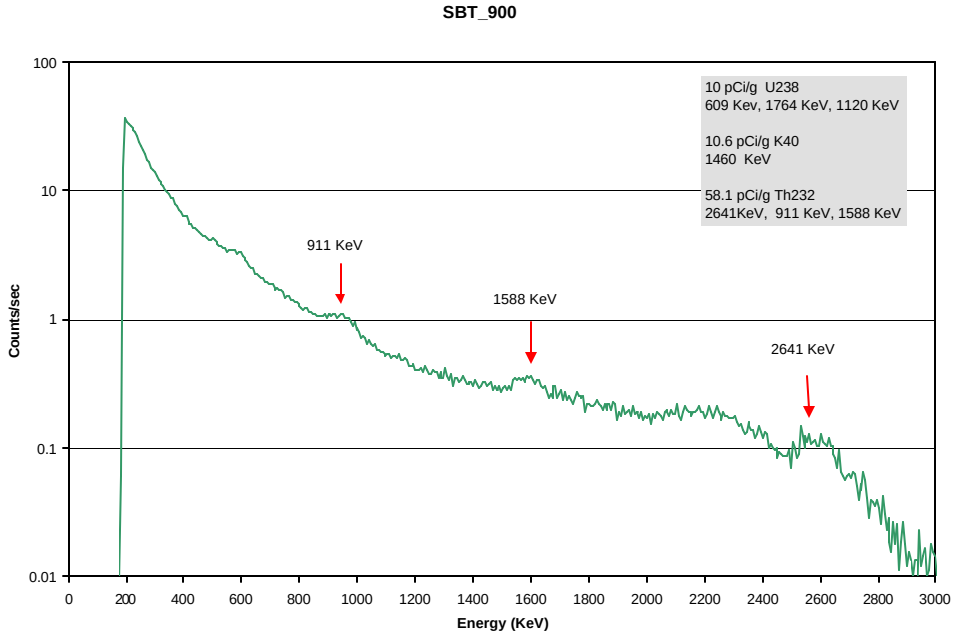


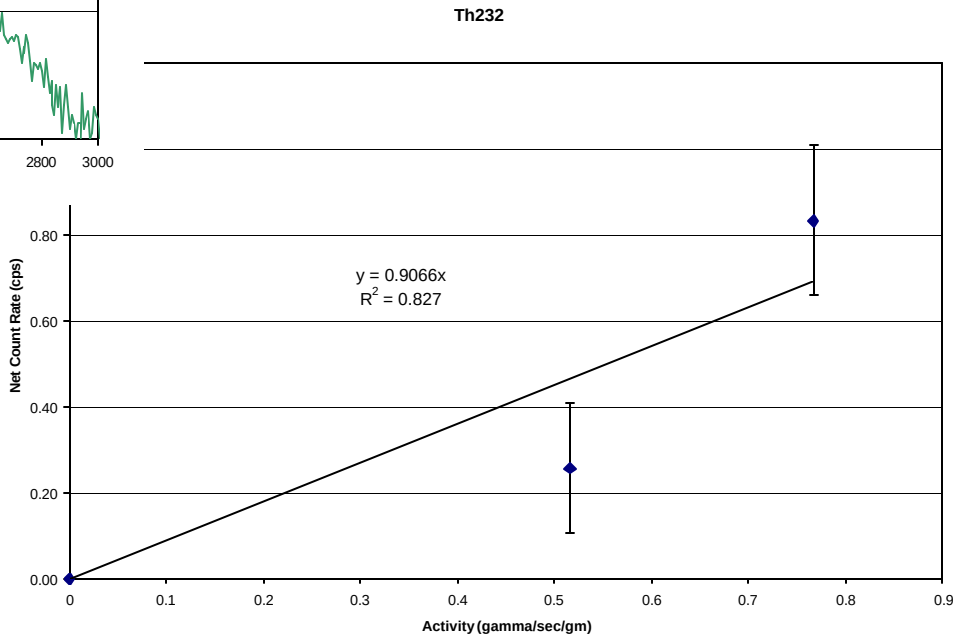
Comparison of Gamma-CPT to Hanford drywell logging system.

- Calibrated probe in natural gamma radionucluide models at the Hanford Site
- Determined inverse efficiency curve to calculate concentrations from net area peaks in collected spectra.
- For Cs^{137}
  - pCi/gm=10.2(cps)
  - γ/sec/gm = 0.17 cps



Natural Gamma Thorium Model





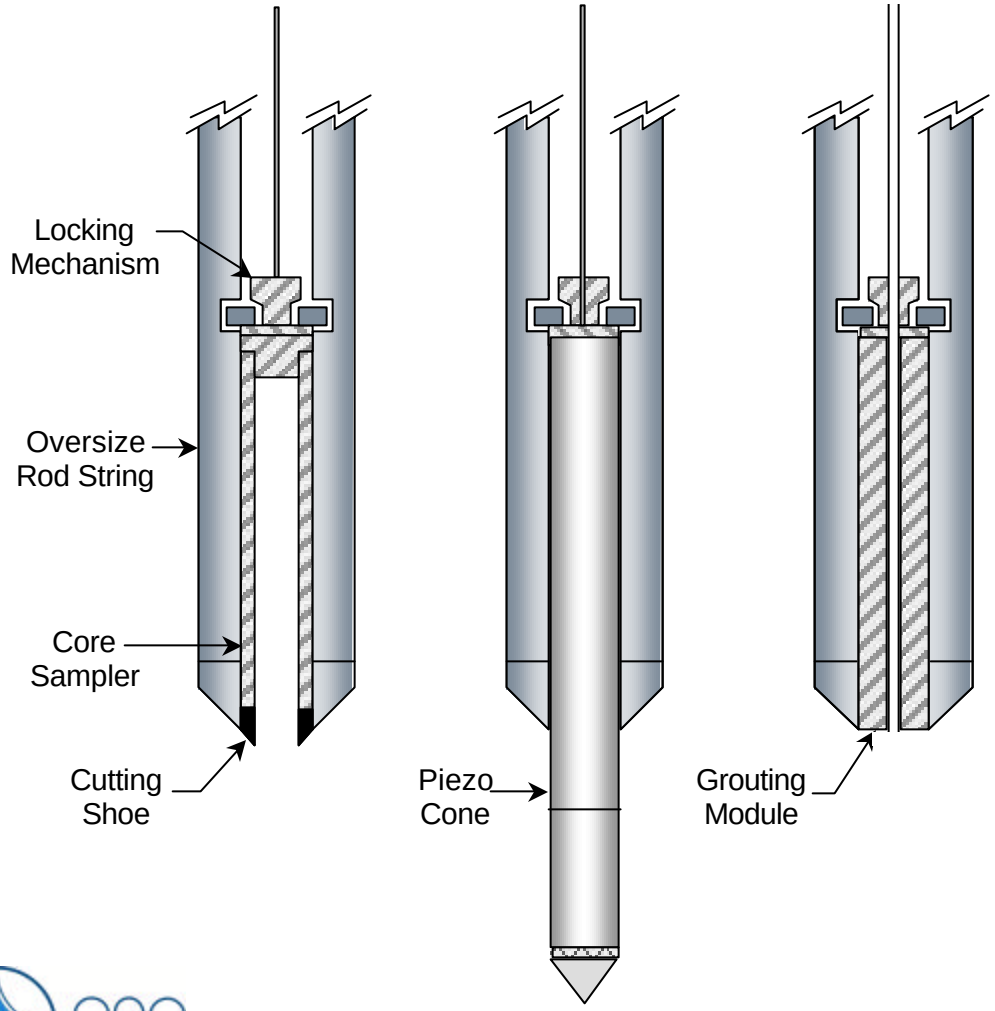
Th^{232} 2614 keV Peak

g/sec/gm = 0.110 (cps)

G-CPT Characterization of the RMAD and Test Cell C leach fields at the Nevada Test Site.

- 80 Penetrations conducted to depths of 5 to 12 feet to characterize random locations selected in the leach field.
- Information used to identify sampling depths and locations for step-outs.
- Gamma-CPT information to be used to determine sampling volumes and if samples can be transported for analysis.
- Data currently under review by DOE-Nevada.

Wireline CPT System

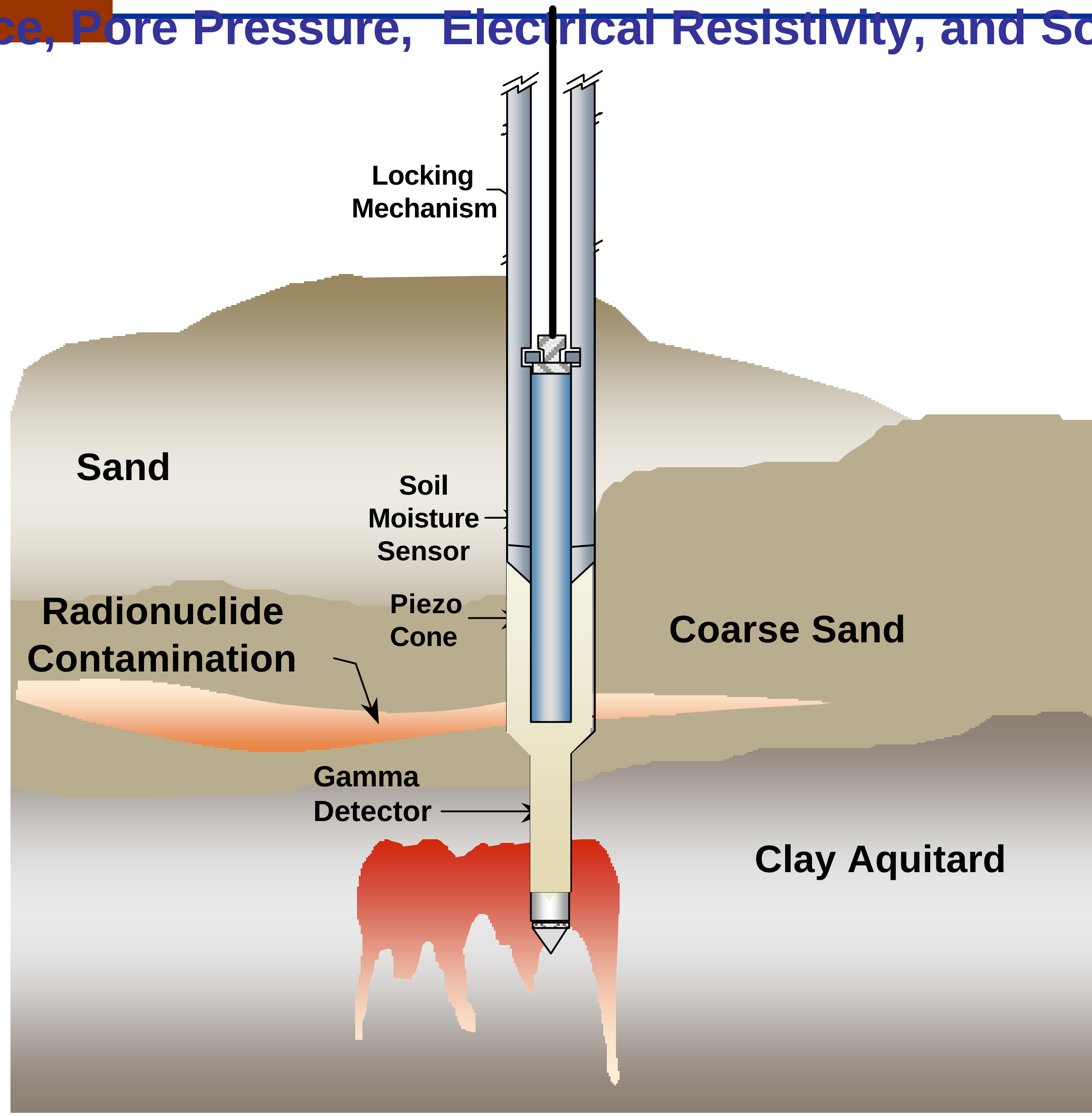


- **Able to exchange tools without removing rods from the ground.**
- **Each tool locks in place near the end of the rods.**
- **Permits various characterization tools to be used during a single characterization (includes samplers).**

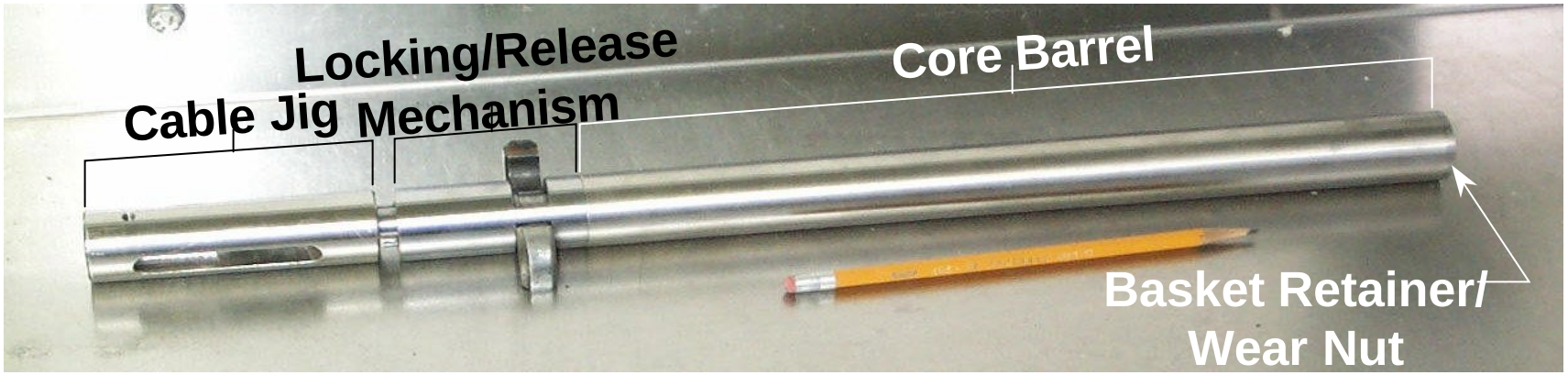
Wireline CPT Benefits

- Reduced time/reduced cost
  - Single penetration for sounding, sampling, sealing
  - Multiple samples from one penetration
- Fewer samples - sensor tells where to sample
  - Lower cost
  - Reduced waste generation
- Reduced risk
  - Sealing confined layers - fewer holes, higher confidence that grout is placed in the original hole

[illegible] Sleeve Resistance, Pore Pressure, Electrical Resistivity, and Soil Moisture



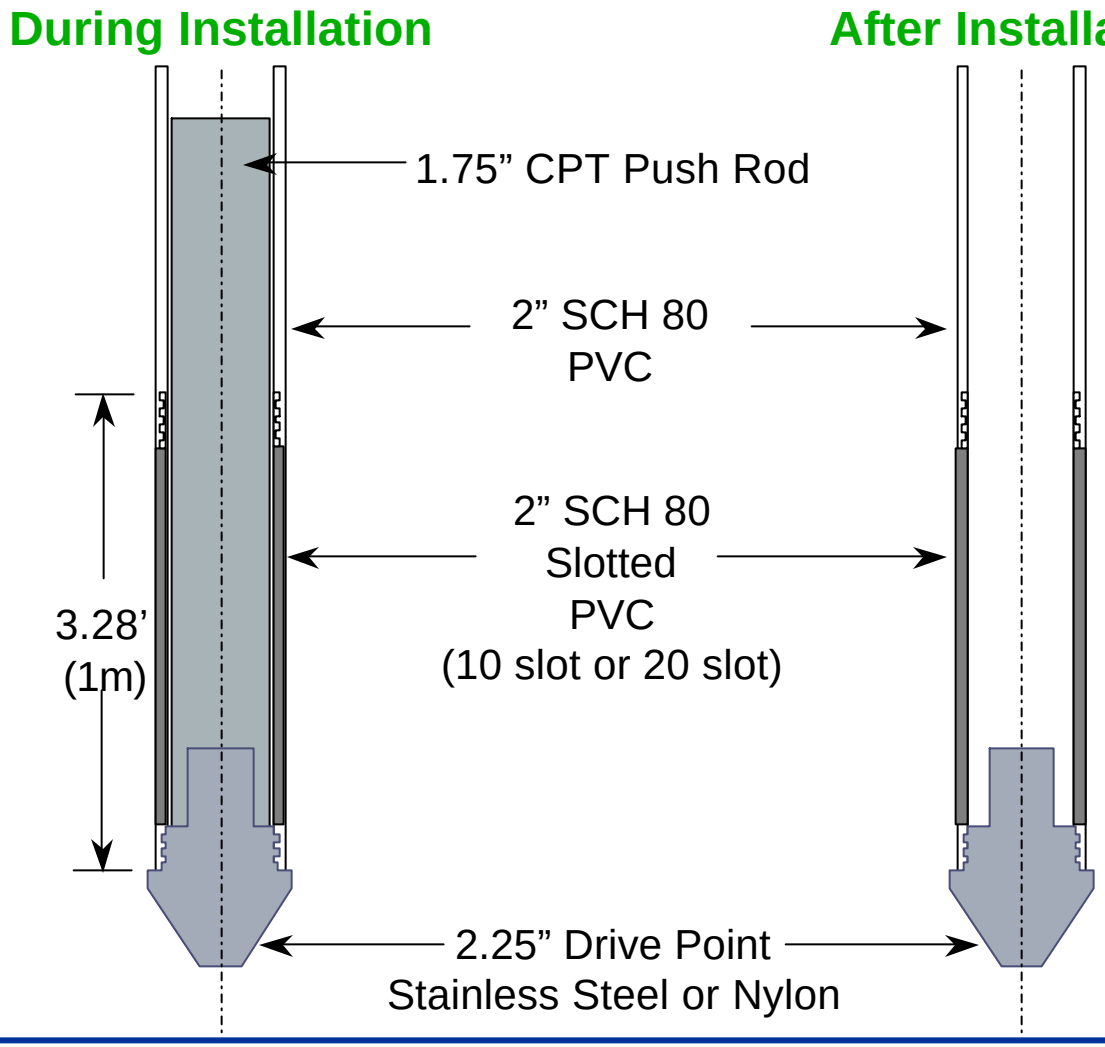
Wireline Soil Sampler



CPT Monitoring systems

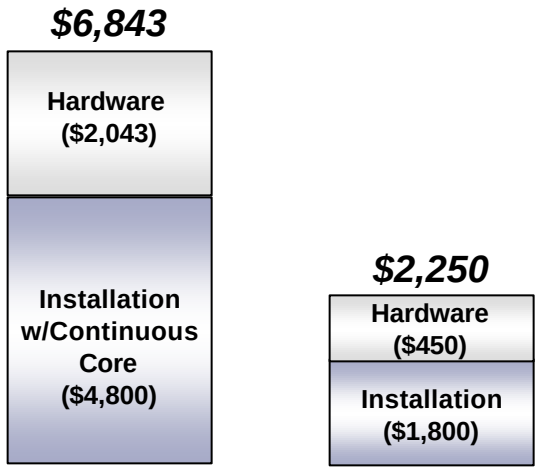
- Most CPT sensors are easily networked.
- ARA has developed a WEB based monitoring system that allows access from any internet terminal using standard web-browser software.
- 2 inch PVC well as also easily installed using CPT.
- CPT can be used to install Advanced Tensiometers from Sission at INEEL.
- Other monitoring approaches such as ERT as also easily accommodated.
- CPT offers significant costs savings over traditational monitor well installation approach.

CPT Installation of Monitoring Wells

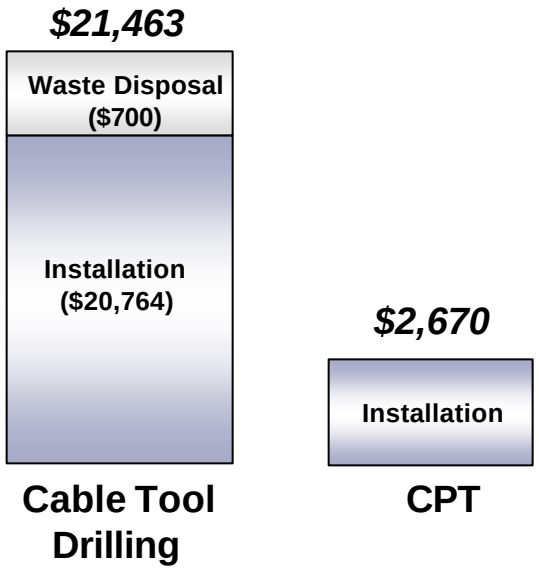


CPT Installed Wells

Installation of a 150 ft Direct Push Well (Savannah River Site)



Installation of a 50 ft Soil Vapor Monitoring Well (Hanford Site)



*Hardware includes, PVC casing, filter pack, bentonite seals, well head, pad

Actual Costs from LANL Environmental Technology Cost-Savings Analysis Project (1991-1995)

CPT Costs

- **Mobilization/ Demobilization:**

  $5,200 (Aiken, SC to OH)

- **Daily Costs: $280/hr (standard work)**
  - daily footage depends on type of work performed but typically 200-300 ft/day
  - Gamma CPT - $380/hr 150-200 ft per day
- **Waste Disposal Costs: minimal**

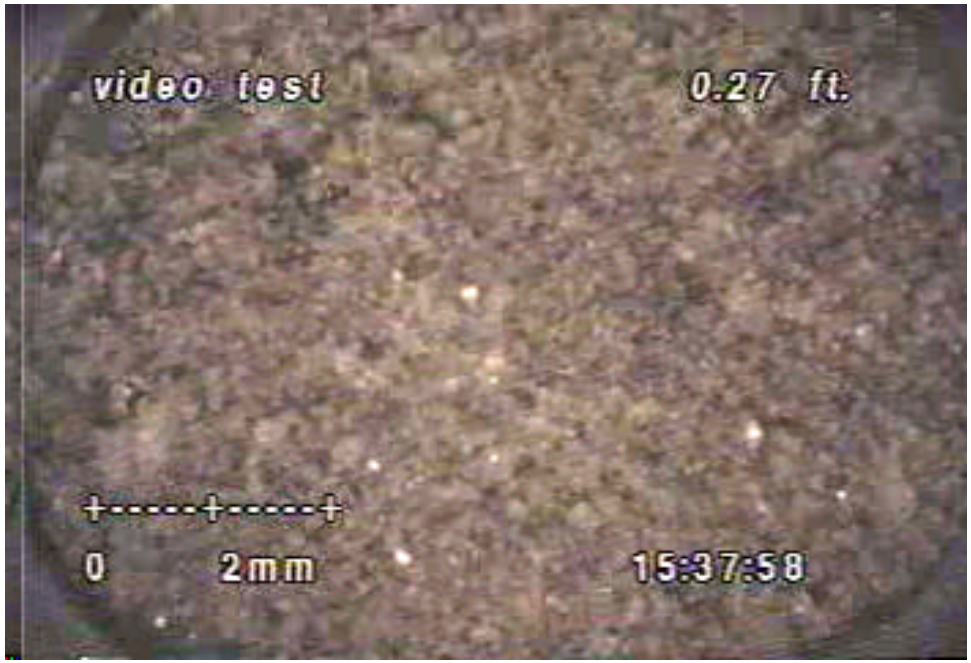
Summary of G-CPT Experience

- Economical and fast method for detecting radiological contamination in-situ.
- Generally able to identify and quantify the contamination type with spectral information.
- Able to delineate regions for sampling as well as regions where contamination is too high to sample.
- Significantly reduces waste generation.
- Rods are wiped clean by soil upon retraction, even in regions of very high contamination.

Summary

- **CPT can have a variety of roles:**
  - Characterization
  - Sampling Activities
  - Monitoring Systems
- **CPT can be used in vadose zone down to the caliche layer in 200 West.**
- **CPT is less expensive than drilling therefore reducing costs or expanding coverage.**
- **ARA soil moisture probe validated in six soil types and three geologies.**
- **Calibration for individual soil samples showed only +/-2% variation from gravimetric determination**

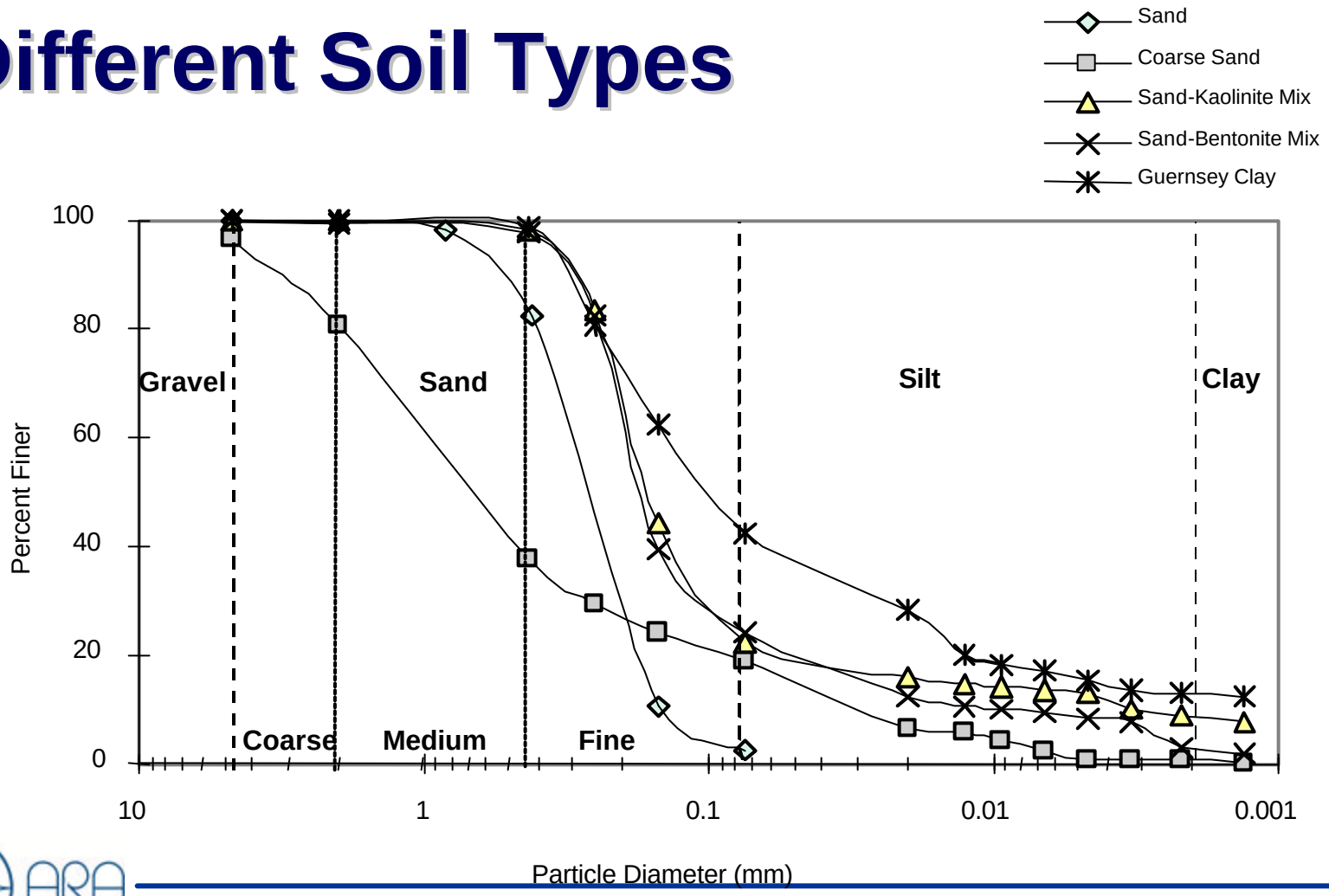
DNAPL Movie



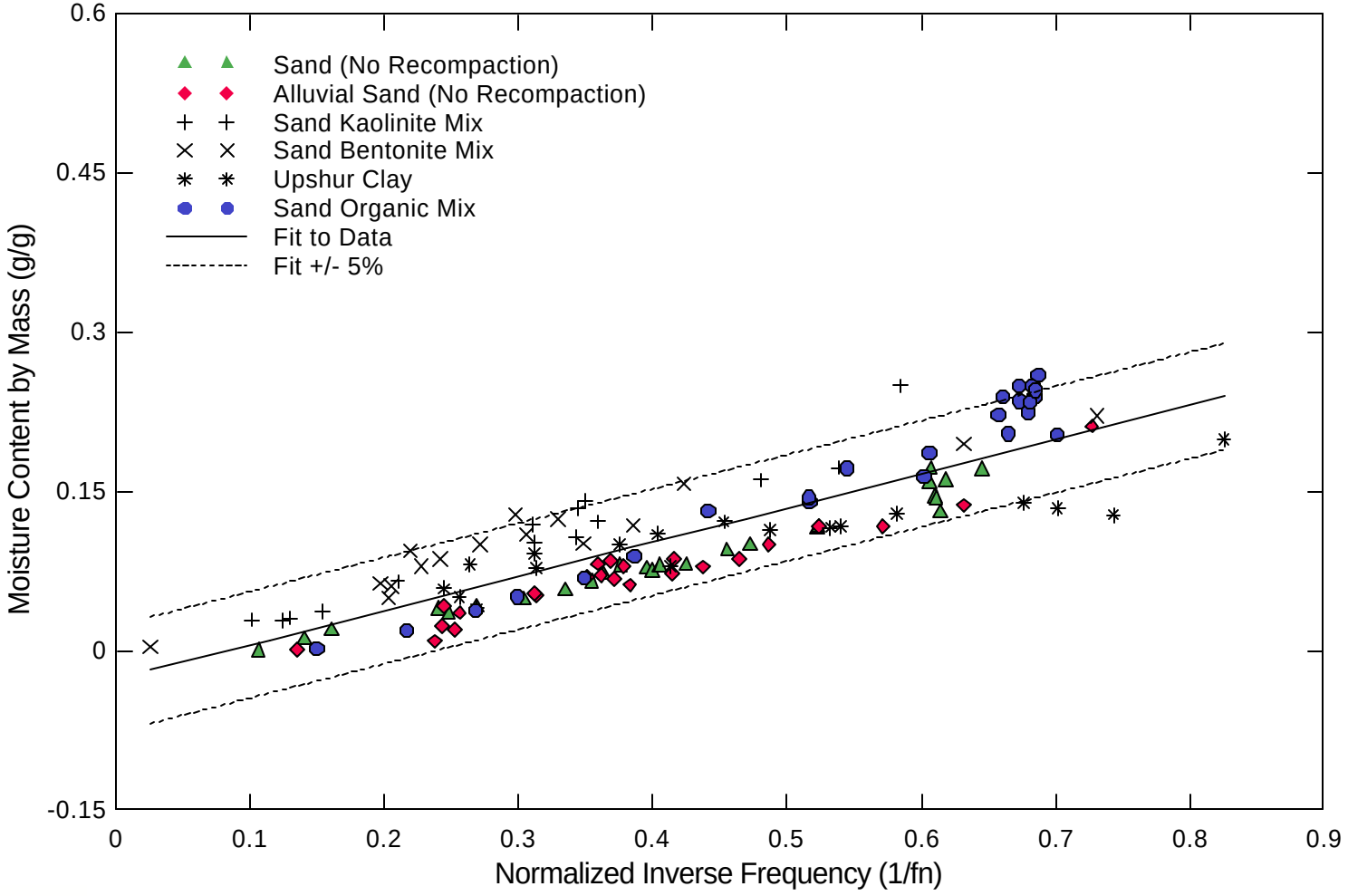
Soil Moisture Probe Development

- Developed CPT probe in 1995
  - CPT probe was evaluated by Argonne National Laboratory under the SCAPS Program
    - ➢Results were most accurate of three moisture sensors tested.
- USDA Phase I study conducted in 1997 for Irrigation Monitoring
  - Laboratory results are presented.
- Working on:
  - USDA Phase II - Additional sensor evaluation and networking.
  - Moisture approach for deep vadose zone applications.

Grain Size Distribution for Different Soil Types



Calibration Response Curve for the Different Soil Types



Penetration CP-04-04